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Note

Objective evaluation of whiteness of cooked rice and rice cakes using a portable spectrophotometer

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The whiteness of cooked rice and rice cakes was evaluated using a portable spectrophotometer with a whiteness index (WI). Also, by using boiled rice for measurement of Mido values by Mido Meter, it was possible to infer the whiteness of cooked rice without rice cooking. In the analysis of varietal differences of cooked rice, 'Tsuyahime', 'Koshihikari' and 'Koshinokaori' showed high whiteness, while 'Satonoyuki' had inferior whiteness. The whiteness of rice cakes made from 'Koyukimochi' and 'Dewanomochi' was higher than the whiteness of those made from 'Himenomochi' and 'Koganemochi'. While there was a significant correlation ($r = 0.84$) between WI values and whiteness scores of cooked rice by the sensory test, no correlation was detected between the whiteness scores and Mido values, indicating that the values obtained by a spectrophotometer differ from those obtained by a Mido Meter. Thus, a spectrophotometer may be a novel device for measurement of rice eating quality.

Key Words: *Oryza sativa* L, color, WI value, eating quality, Mido Meter, whiteness score, sensory test.

Introduction

Eating qualities for both cooked rice and waxy rice cakes are the most important traits for rice breeding in Japan. The overall eating quality of cooked rice is assessed by sensory tests, in which appearance, taste, aroma, stickiness and hardness of breeding lines are compared with those of a standard variety (Matue 1992, Yamamoto *et al.* 1996). The overall eating quality of rice cakes is also assessed by the sensory test of appearance, whiteness, hardness, stickiness, stretchiness, taste and texture (Kobayashi *et al.* 2002). Although the sensory test is the most reliable test among the methods for evaluation of eating quality, it requires a large amount of samples, many panelists and a long time (Lestari *et al.* 2009, Wada *et al.* 2008). Therefore, a method for evaluation of the eating quality of cooked rice and rice cakes which enables examination of many samples within a short time without use of panelists is required.

Since gloss, stickiness and taste contribute largely to the overall judgment of cooked rice (Matsue *et al.* 1991, Ramesh *et al.* 2000), studies on Mido Meter related to the gloss of cooked rice (Sato *et al.* 2003), contents of amylose (Okuno *et al.* 1983, Ramesh *et al.* 2000) and protein (Juliano 1985) responsible for stickiness and contents of sugar (Ikeda 2001, Kasai *et al.* 2000) and amino acids (Kamara *et al.* 2010, Tran *et al.* 2004, 2005) involved in taste have been performed. Genetic analyses of these traits have also been carried out for development of novel DNA maker-assisted selection techniques (Kwon *et al.* 2011, Takeuchi *et al.* 2007, Wada *et al.* 2008). Although for parboiled rice, an evaluation method of whiteness, which is an important factor in the appearance (Lv *et al.* 2009), has been studied, methods to evaluate whiteness for selection of breeding lines have not been developed. There are devices by which whiteness of brown rice and white rice without cooking can be analyzed, e.g., Rice Whiteness Tester (Kett, C-300), but no device for the measurement of the whiteness of cooked rice. Similarly in rice cakes, the whiteness has not been studied, although the chain length of amylopectin,

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which is responsible for hardenability, has been intensively studied (Igarashi *et al.* 2008).

In the present study, the possibility of objective evaluation of the whiteness of cooked rice and rice cakes using a portable spectrophotometer was examined. The Mido values obtained by Mido Meter and the whiteness values were compared and a measuring method without rice cooking was tested. Factors influencing the whiteness of cooked rice are discussed. In this paper, "whiteness" is used as a general term, "whiteness score" indicates whiteness rated by a sensory test and "WI value" indicates whiteness measured by a spectrophotometer.

Materials and Methods

Preparation of cooked rice and rice cakes

Grains of rice (*Oryza sativa* L.) harvested in the Rice Breeding and Crop Science Experiment Station of the Yamagata Integrated Agricultural Research Center from 2010 to 2012 were used. Eleven non-glutinous cultivars that can be cultivated in Yamagata Prefecture, i.e., 'Hananomai', 'Satonoyuki', 'Akitakomachi', 'Domannaka', 'Sasanishiki', 'Hitomebore', 'Haenuki', 'Koshihikari', 'Tsuyahime', 'Koshinokaori' and 'Fukuhibiki' and some lines under breeding programs (Supplemental Table 1) were examined with 'Haenuki' and 'Tsuyahime' produced separately as a standard cultivar and a reference cultivar, respectively. Four glutinous cultivars, i.e., 'Himenomochi', 'Koyukimochi', 'Dewakomochi' and 'Koganemochi' and some breeding lines (Supplemental Table 1) were tested with 'Himenomochi' produced separately as a standard cultivar. Seeds were sown in the second decade of April and plants were transplanted to a paddy field at 22.2 planting positions/m^2 with five plants per position in the second decade of May. Fertilizer was 0.7 Nkg/a, but only for 'Akitakomachi' and 'Hitomebore' cultivated in 2010, a plot with 0.9 Nkg/a was added. Grains were harvested from 96 or 128 plants in the period of maturity from the end of August to the beginning of October, when accumulated temperature from the heading date became 950–1,100°C. Brown rice grains smaller than 1.9 mm in non-glutinous rice and 1.8 mm in glutinous rice were removed by sieves.

The brown rice grains were polished by a rice-polishing machine (Yamamoto Seisakusho, VP-30T) to make white rice weighing 90% of the weight of brown rice. Using grains of 'Haenuki' harvested in 2010, white rice grains weighing 88%, 89%, 90%, 91% and 92% of the weight of brown rice were also prepared. Water weighing 1.33 times (w/w) the weight of white rice was added to 350 g white rice of non-glutinous cultivars and kept for 1 h. The rice was cooked using an electric rice cooker (Toshiba Co. Ltd., RCK-5DG). After being switched off, the rice cooker was kept for 10 min to steam the boiled rice and stirred with a rice scoop. Some cooked rice (20–30 g) was placed in a sealed glass Petri dish and the rest was subjected to sensory tests.

Using 1 kg white rice of glutinous cultivars, rice cakes were prepared by an electric rice cake maker (Toshiba, AFC-10F). After pounding steamed rice, a hot rice cake was extended to make it 10 mm thick, hardened at 5°C for 24 h and cut into a 27 × 27-mm square. Three pieces of rice cake were used for measurement of whiteness. Other pieces of the rice cake were subjected to sensory tests after both sides were heated by a hot plate (Toshiba, HGM-3SB) at 200°C for 2.5 min, avoiding burnt deposits.

The sensory tests were performed by 16–24 panelists of the Rice Breeding and Crop Science Experiment Station. In the tests of cooked non-glutinous rice, appearance, glossiness, whiteness, aroma, taste, stickiness, hardness and overall judgment were evaluated. For rice cakes, appearance, whiteness, taste, stretchiness, texture, hardness and overall judgment were scored. Whiteness scores from –3 to +3 given by all the panelists were averaged. Scores of whiteness were as follows: +3, much whiter; +2, moderately whiter; +1 slightly whiter; 0, comparable to the standard; –1, slightly less white; –2, moderately less white; –3, extremely less white. The whiteness scores of 'Haenuki' and 'Tsuyahime' were set at 0 and +1, respectively and the score for rice cakes made from 'Himenomochi' was set at 0 and the same scale as that for cooked rice was applied to scoring of rice cakes.

Measurement by a spectrophotometer

Using a portable spectrophotometer (Konica Minolta, CM-600D), whiteness was measured. The mode of measurement was SCE (specular component excluded) and values of whiteness were colorimetric data of whiteness index (WI) value (ASTM E313-73). For some samples, reflectance values of light from 400 nm to 700 nm with wavelength pitch of 10 nm were measured and values of L*, a* and b* were calculated.

The cooked rice in a sealed glass Petri dish was kept at 20°C for 2 h and 8 g of cooked rice was formed into a cylindrical shape with a diameter of 32 mm and a height of 9 mm. Three cylinders were prepared and the WI values at the center of both sides of the cylinders were measured. In rice samples after measurement of Mido values by a Mido Meter (TOYO, MA-90A), an accessory ring of the Mido Meter was carefully removed to maintain the cylindrical shape and the rice cylinder was cooled for 10 min. The WI values of three points of both the top and bottom surfaces of the cylinder were measured and averaged. The WI values of rice cakes were measured at the center of the top and bottom surfaces, not the cut sections and the values of three samples were averaged.

Contents of protein and amylose

Protein content of white rice was measured by far-red light transmission using a grain analyzer (Shizuoka Seiki, AG-RD). Amylose content was analyzed by AutoAnalyzer II (Bran + Luebbe, AutoAnalyzer II) using iodine colorimetric determination after milling of white rice by a test

mill (Brabender, 279002) and obtained values were converted to values of samples having 15% water content.

Results

Comparison of values obtained by a portable spectrophotometer and those by a sensory test

The whiteness scores of cooked rice by the sensory test increased from –1.50 to 0.94 following a decrease of rice-polishing rates from 92% to 88%. The WI values also showed increase from 25.4 (92%) to 38.6 (89%). A highly significant positive correlation, the correlation coefficient, r, being 0.97, was observed between the WI values of cooked rice samples with the cylindrical shape and the whiteness scores of the sensory test (Supplemental Fig. 1). In analysis of different cultivars, the WI values in 2010 ranged from 30.6 for 'Satonoyuki' to 41.6 for 'Koshinokaori' (Fig. 1). 'Tsuyahime' showed the second highest WI value, i.e., 41.0, followed by 'Koshihikari', i.e., 39.2 (Fig. 1). The whiteness scores of these cultivars evaluated by the sensory test ranged from –0.46 for 'Akitakomachi' to 1.29 for 'Koshinokaori' and a significant correlation (r = 0.84) between the whiteness scores of the sensory test and the WI values was observed (Fig. 2). The whiteness scores evaluated in 2011 by the sensory test were from –0.38 for 'Satonoyuki' to 0.70 for 'Tsuyahime' and the WI values ranged from 31.7 for 'Satonoyuki' to 40.0 for 'Tsuyahime'. There was also a significant correlation (r = 0.71) between the whiteness scores of the sensory test and the WI values (Supplemental Fig. 2). In the analysis of whiteness in 2012, breeding lines were also investigated together with the cultivars. A significant correlation between the sensory test scores (–0.80 to 0.65) and the WI values (31.8 to 41.6) was again detected (r = 0.73) (Supplemental Fig. 3).

The WI values of the samples of the Mido Meter ranged from 8.5 for 'Akitakomachi' to 23.7 for 'Koshinokaori' in the analysis of 2010 and showed a significantly high correlation (r = 0.88) with the whiteness scores by the sensory test (Fig. 3). Mido values ranging from 39 for 'Koshinokaori' to 82 for 'Tsuyahime' and 'Hitomebore' had no correlation with the WI values (Supplemental Fig. 4) and the whiteness scores by the sensory test (Fig. 4). In the samples of 2012 including the breeding lines, the WI values of the Mido Meter samples were from 11.7 to 22.6 with a significant correlation with the whiteness scores (r = 0.62) (Supplemental Fig. 5).

The whiteness scores of rice cakes by the sensory test ranged from 0.38 to 0.79 in 2010. The WI values, being 18.2 to 24.9, exhibited a significantly high correlation (r = 0.66) with the whiteness scores of the sensory test (Supplemental Fig. 6). Investigation in 2011 also showed a significant correlation (r = 0.67) between the whiteness scores of the sensory test from –0.45 to 0.80 and the WI

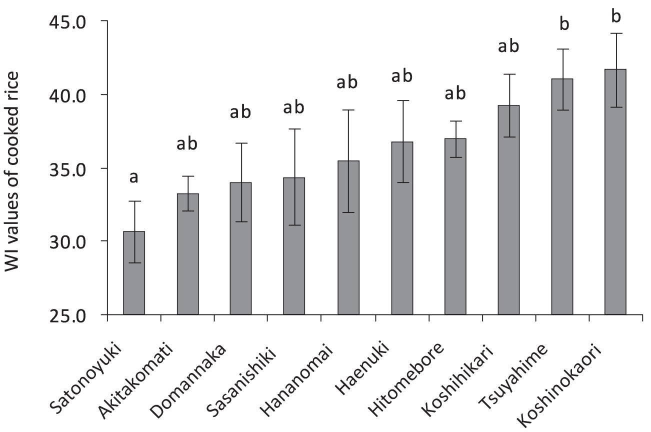

Fig. 1. Varietal differences of the WI values of cooked rice measured in 2010. Vertical bars represent SD (n = 6). Means with the same letter are not significantly different from each other (Tukey test, P < 0.05). Fertilizer was 0.7 Nkg/a. Brown rice grains of all the cultivars were polished to obtain white rice weighing 90%.

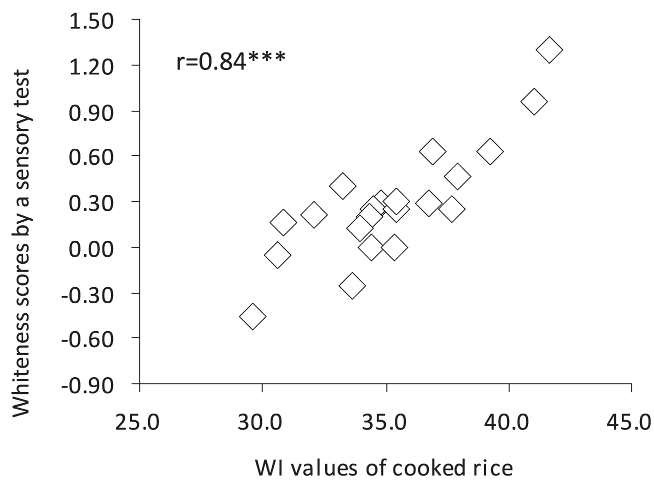

Fig. 2. Correlation between the WI values of cylindrically shaped cooked rice samples and the whiteness scores by a sensory test performed in 2010. ***: significant at the 0.1% level.

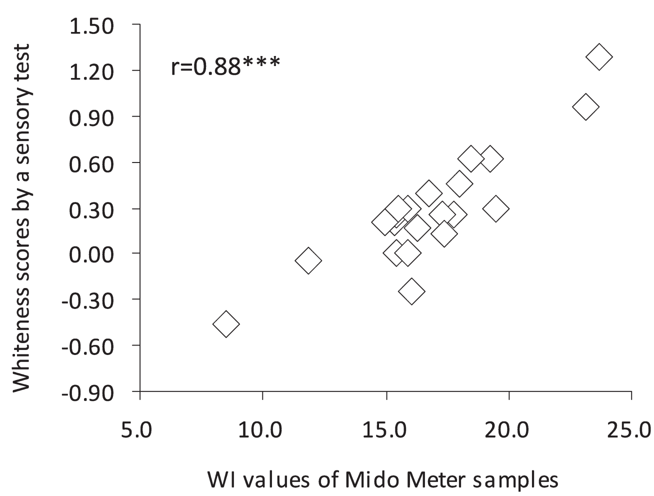

Fig. 3. Correlation between the WI values of Mido Meter samples and the whiteness scores by a sensory test performed in 2010. ***: significant at the 0.1% level.

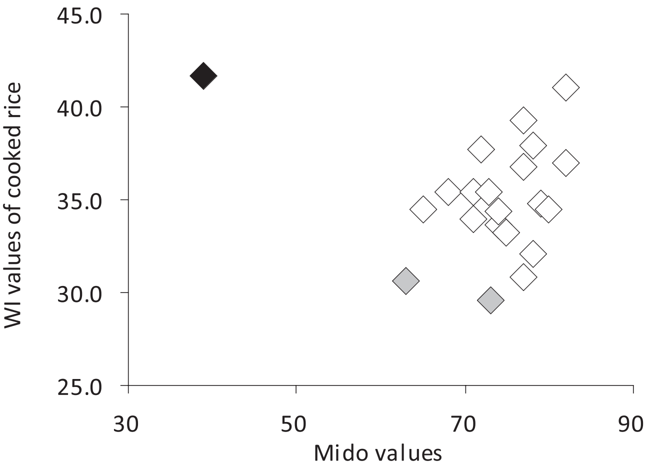

Fig. 4. Relationship between the whiteness scores and Mido values measured in 2010. The black diamond indicates high-amylose cultivar ‘Koshinokaori’ and gray diamonds indicate low-amylose cultivar ‘Satonoyuki’.

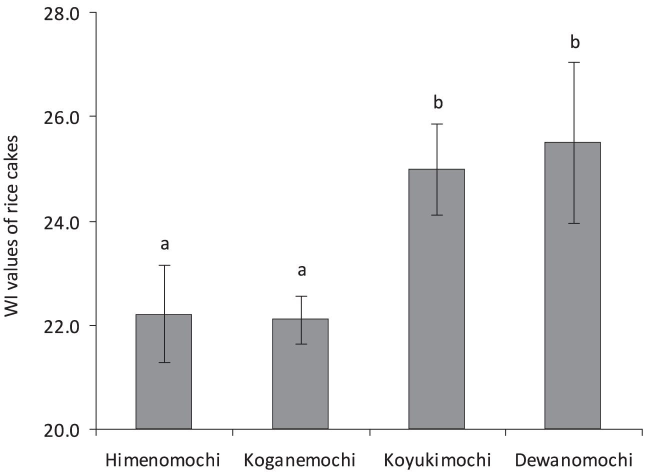

Fig. 5. Varietal differences of the WI values of rice cakes measured in 2012. Vertical bars represent SD (n = 6). Means with the same letter are not significantly different from each other (Tukey test, P < 0.05).

values from 18.6 to 25.1 (Supplemental Fig. 7). The WI values of ‘Koyukimochi’ and ‘Dewakomochi’, being 25.0 and 25.5, respectively, in 2012, were higher than the standard varieties, i.e., ‘Himenomochi’ and ‘Koganemochi’, the WI values of which were 22.2 and 22.1, respectively (Fig. 5). The WI values in 2012 again showed significantly high correlation (r = 0.87) with the whiteness scores ranging from –0.13 to 0.50 (Supplemental Fig. 8).

Reflectance values and L, a*, b* of samples having the different WI values*

The average WI value of ‘Tsuyahime’ was 41.0, being higher than 34.8 of ‘Haenuki’ and 37.9 of ‘Koshihikari’. In ‘Tsuyahime’, reflectance values of 400–550 nm were 2% higher than those of ‘Haenuki’ and ‘Koshihikari’. At 550–700 nm, reflectance values of ‘Koshihikari’ were 1% lower than those of ‘Haenuki’ and ‘Tsuyahime’ (Fig. 6). While

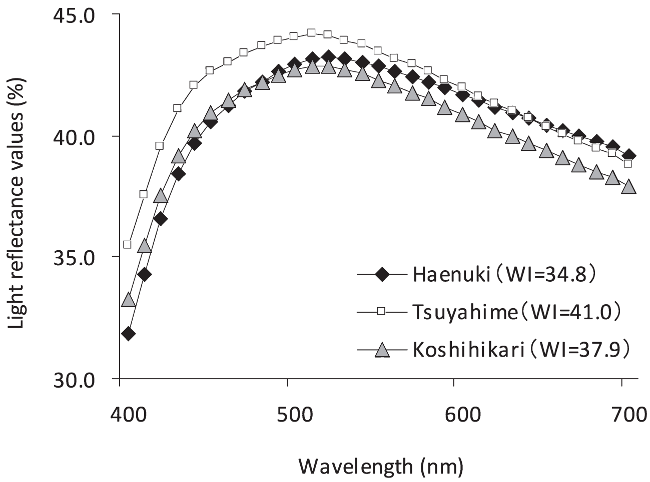

Fig. 6. Light reflectance values of cooked rice samples having different the WI values.

Table 1. The WI values and L*a*b* values of cylindrically shaped cooked rice samples having different whiteness scores[a]

Cultivar	WI	L*	a*	b*
Haenuki	34.8 ± 2.5	71.1[a] ± 0.5	–2.6[a] ± 0.1	2.6[a] ± 0.8
Tsuyahime	41.0 ± 1.9	71.6[a] ± 0.7	–2.6[a] ± 0.1	0.9[b] ± 0.4
Koshihikari	37.9 ± 3.0	70.7[a] ± 1.2	–2.7[a] ± 0.1	1.5[b] ± 0.5

Values in the table are means ± standard deviation.
Means with the same letter are not significantly different from each other (Tukey test, P < 0.05).

there was no difference in L* and a* between the three varieties, b* of ‘Tsuyahime’, being 0.9, was the lowest, followed by 1.5 of ‘Koshihikari’ and 2.6 of ‘Haenuki’ (Table 1).

Relationship of whiteness with the contents of amylose and protein

Amylose contents ranged from 9.9 to 20.9%. There was a significant positive correlation (r = 0.31) between the amylose contents and the WI values ranging from 31.8 to 41.6 (Supplemental Fig. 9). However, removal of two cultivars having amylose contents lower than 15% made that correlation nonsignificant (r = –0.13). Protein contents were from 5.9% to 7.2%. A significant negative correlation (r = –0.33) was observed between protein contents and the WI values. Especially, samples having protein contents more than 6.5% showed a tendency to have lower whiteness (Supplemental Fig. 10).

Discussion

Evaluation of whiteness using a portable spectrophotometer

There were high positive correlations between the WI values of cylindrically shaped cooked rice samples and the whiteness scores of the sensory test of different cultivars and different rice-polishing rates, indicating that the sensory test can be replaced with the measurement of whiteness

using a portable spectrophotometer. The portable spectrophotometer may become a novel measurement device for evaluation of rice eating quality. The Mido Meter is a device for measuring the appearance of rice. This device quantifies the depth of the water retention membrane on the surface of cooked rice to measure the gloss of cooked rice. The present study was performed to evaluate the whiteness of cooked rice using two devices, a portable spectrophotometer and a Mido meter. There was a significant correlation ($r = 0.84$, 2010) between the whiteness scores in the sensory evaluation and WI of the cooked rice, which was an important factor relating to rice eating quality. In addition, it was higher than the correlation between Mido value and the sensory evaluation ($r = -0.26$, 2010). The results indicate that WI evaluation during Mido analysis is useful for prediction of whiteness of cooked rice. The portable spectrophotometer may be a novel device for efficient determination of rice eating quality.

Cooked rice samples having the high WI values showed high b^* values. Reflectance values of blue light at 450–500 nm in wavelength were high and those of yellow light at 600 nm in wavelength were low in these samples. These results suggest that reflectance of blue light and yellow light is highly related to the whiteness of cooked rice.

The high positive correlation between the WI values of the samples prepared for the Mido Meter and the whiteness scores by the sensory test observed in the present study indicates that gelatinization of only the surface of rice grains is sufficient for evaluation of the whiteness of cooked rice. However, the correlation coefficient of the data obtained in 2012 was lower than those between the WI values of cooked rice samples and the scores of the sensory test, indicating that measurement of the WI values of cooked rice is more reliable for evaluation of the whiteness.

Similarly to the results of cooked rice, evaluation of the whiteness of rice cakes was also found to be possible by using a portable spectrophotometer. The method adopted for preparation of rice cakes in the present study requires 1 kg of glutinous rice. However, the method reported by Ishizaki (1994) enables preparation of rice cakes from a small amount of glutinous rice and may contribute to improving the efficiency in breeding of glutinous cultivars.

Varietal difference of whiteness

The WI values of 'Koshinokaori', 'Tsuyahime' and 'Koshihikari' were high, while that of 'Satonoyuki' was low. One possible explanation of the low whiteness of 'Satonoyuki' is its low content of amylose, which is 7–14% (Tateyama *et al.* 2005). 'Satonoyuki' has *Wx-y*, which is an allele of *Wx* causing low amylose content. A breeding line having the *Wx-y* allele tested in 2012, the amylose content of which was 9.9%, also showed low whiteness. 'Koshinokaori', which has a high amylose content (Osawa and Inoue 2008), showed the highest WI value among the cultivars tested in 2010. These results suggest that amylose contents influence the whiteness of cooked rice.

High whiteness of 'Tsuyahime' and 'Hananomai', which have amylose contents comparable to those of other cultivars, may be due to other factors. Although protein contents had negative correlation with whiteness, protein contents of 'Tsuyahime' (6.4%) and 'Hananomai' (6.6%) were comparable to those of other cultivars, indicating that protein contents are also not a cause of the high whiteness of these cultivars. Since different rice-polishing rates largely affect whiteness, the thickness of the aleurone layer might be responsible for the high whiteness in these cultivars.

Differences were observed in the WI values and the whiteness scores of rice cakes made from different cultivars. Since amylose contents of these glutinous cultivars were 0%, the difference of whiteness is due to other factors. Protein contents and the thickness of the aleurone layer may have some effect on the whiteness of rice cakes. However, further analysis is required for elucidation of the causes of varietal differences of the whiteness.

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Literature Cited

Igarashi, T., M. Kinoshita, H. Kanda, T. Nakamori and T. Kusume (2008) Evaluation of hardness of waxy rice cake based on the amylopectin chain-length distribution. J. Appl. Glycosci. 55: 13–19.

Ikeda, H. (2001) Relationship between the saccharides extracted from rice grains during cooking and the sensory taste of cooked rice. J. Home Econ. Jpn. 52: 401–409.

Ishizaki, K. (1994) Studies on processing suitability of glutinous rice. 1. Simple measurement of hardness of mochi dough. Hokuriku Crop Sci. 29: 26–28.

Juliano, B.O. (1985) Criteria and test for rice grain quality. *In*: Juliano, B.O. (ed.) Rice Chemistry and Technology, American Association of Cereal Chemists, Saint Paul, pp. 443–513.

Kamara, J.S., S. Konishi, T. Sasanuma and T. Abe (2010) Variation in free amino acid profile among some rice (*Oryza sativa* L.) cultivars. Breed. Sci. 60: 46–54.

Kasai, M., K. Ishiguro, H. Kyouda, T. Hanazono, K. Hatae and A. Shimada (2000) Change in the amounts of reducing sugars and free amino acids in rice during the cooking processes. J. Home Econ. Jpn. 57: 579–585.

Kobayashi, K., T. Matsui, H. Kasaneyama, K. Ishizaki and S. Abe (2002) Method of testing palatability of glutinous rice-cake. Jpn. J. Crop Sci. 71: 250–255.

Kwon, S., Y. Cho, J. Lee, J. Suh, J. Kim, M. Kim, I. Choi, H. Hwang,

H. Koh and Y. Kim (2011) Identification of quantitative trait loci associated with rice eating quality traits using population of recombinant inbred lines derived from a cross between two temperate *japonica* cultivars. Mol. Cells. 31: 437–445.

Lestari, P., T. Ham, H. Lee, M. Woo, W. Jiang, S. Chu, S. Kwon, K. Ma, J. Lee, Y. Cho *et al.* (2009) PCR marker-based evaluation of the eating quality of *japonica* rice (*Oryza sativa* L.). J. Agric. Food Chem. 57: 2754–2762.

Lv, B., B. Li, S. Chen, J. Chen and B. Zhu (2009) Comparison of color techniques to measure the color of parboiled rice. J. Cereal Sci. 50: 262–265.

Matsue, Y. (1992) On a sensory test of cooked rice in which 10 cultivars were evaluated by 13 panel members. J. Home Econ. Jpn. 43: 1027–1032.

Matsue, Y., K. Mizuta and T. Yoshida (1991) Varietal difference in palatability of stored rice. Jpn. J. Crop Sci. 60: 537–542.

Okuno, K., H. Fuwa and M. Yano (1983) A new mutant gene lowering amylase content in endosperm starch of rice, *Oryza sativa* L. Jpn. J. Breed. 33: 387–394.

Osawa, M. and N. Inoue (2008) Principal component analysis of starch digestibility and physicochemical properties related to texture of rice. Jpn. J. Crop Sci. 77: 61–68.

Ramesh, M., K.R. Bhattacharya and J.R. Mitchell (2000) Developments in understanding the basis of cooked-rice texture. Crit. Rev. Food Sci. Nutr. 40: 449–460.

Sato, H., S. Saito and T. Taira (2003) Selection for high palatable rice lines by use of Mido Meter and rapid Visco analyzer. Jpn. J. Crop Sci. 72: 390–394.

Takeuchi, Y., Y. Nonoue, T. Ebitani, K. Suzuki, N. Aoki, H. Sato, O. Ikeda, H. Hirabayashi, M. Hirayama, H. Ohta *et al.* (2007) QTL detection for eating quality including glossiness, stickiness, taste and hardness of cooked rice. Breed. Sci. 57: 231–242.

Tateyama, M., M. Sakai and M. Suto (2005) Varietal differences in the response of amylose content of endosperm of low-amylose rice (*Oryza sativa* L.) lines to temperature during the ripening period. Breed. Rese. 7: 1–7.

Tran, T.U., K. Suzuki, H. Okadome, S. Homma and K. Ohstubo (2004) Analysis of the tastes of brown rice and milled rice with different milling yields using a taste sensing. Food Chem. 88: 557–566.

Tran, T.U., K. Suzuki, H. Okadome, H. Ikezaki and S. Homma (2005) Detection of changes in taste of *japonica* and *indica* brown and milled rice (*Oryza sativa* L.) during storage using physicochemical analyses and taste sensing system. J. Agri. Food Chem. 53: 1108–1118.

Wada, T., T. Ogata, M. Tsubone, Y. Uchimura and Y. Matsue (2008) Mapping of QTLs for eating quality and physicochemical properties of the *japonica* rice 'Koshihikari'. Breed. Sci. 58: 427–435.

Yamamoto, T., N. Horisue and R. Ikeda (1996) Rice breeding manual. Yokendo Ltd., Tokyo, pp. 74–124.